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# High Power Electric Propulsion for Space Solar Power Satellites

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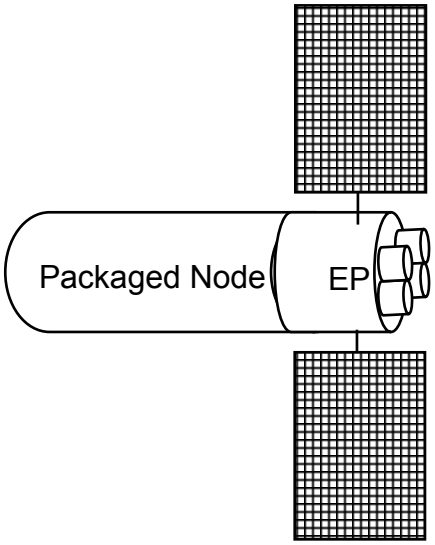
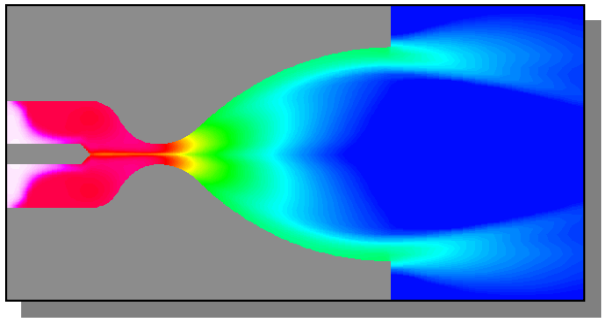
6.10.02



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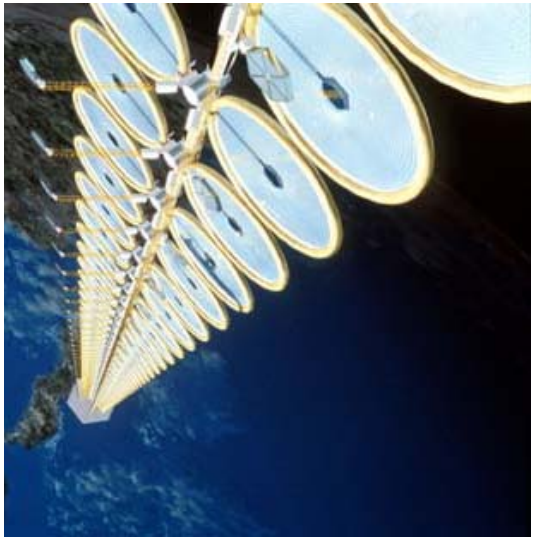
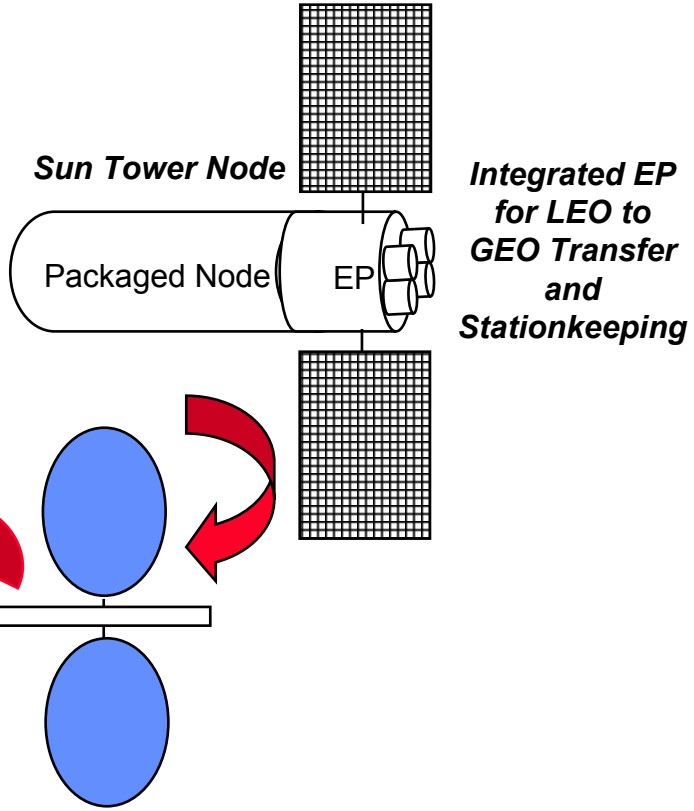
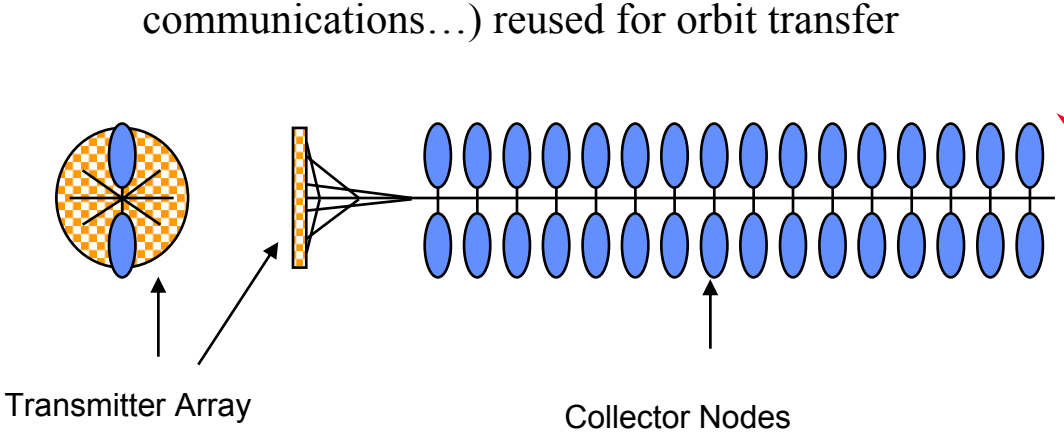
# Mission Analysis



- 'Sun Tower' option used for Propulsion system trades
- Assembled Specs: 1.2 GW collection power, 400 MW on the ground, 6000 metric tons in GEO, >20 year life.
- Hundreds of large MWe class power collecting 'nodes' delivered to geosynchronous orbit.
- Launch system places 20 MT into 28.5°, 300 km low earth orbit
- Node power system not deployable until assembly with other nodes in GEO (current structures team assessment)
- A 200 kW array added with on-board electric propulsion (EP) to the node for LEO to GEO transfer
- Support systems of node (attitude control, guidance, communications…) reused for orbit transfer



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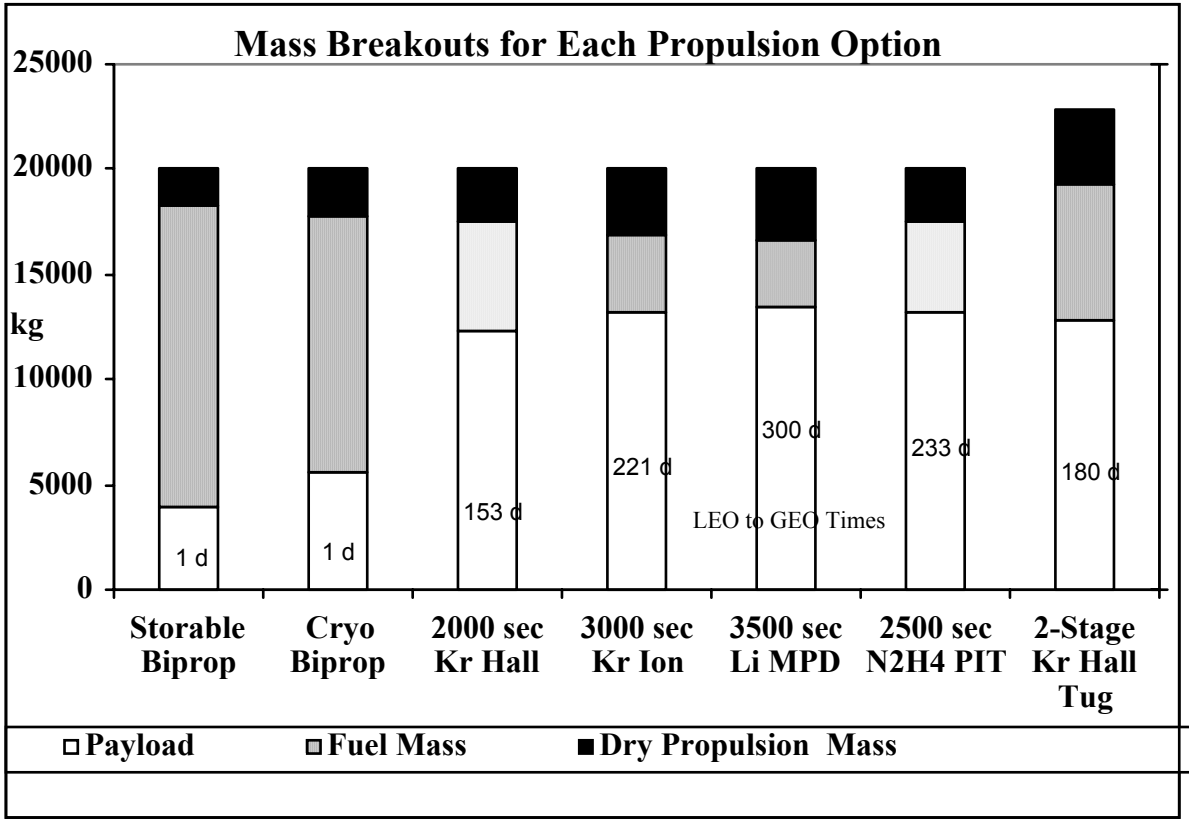
# Delivered Mass and Trip Times




- All Electric Propulsion Concepts more than double the payload mass compared to chemical
- Hall gives the best balance of payload and trip time
- Tug concept gives no advantage over on-board concept

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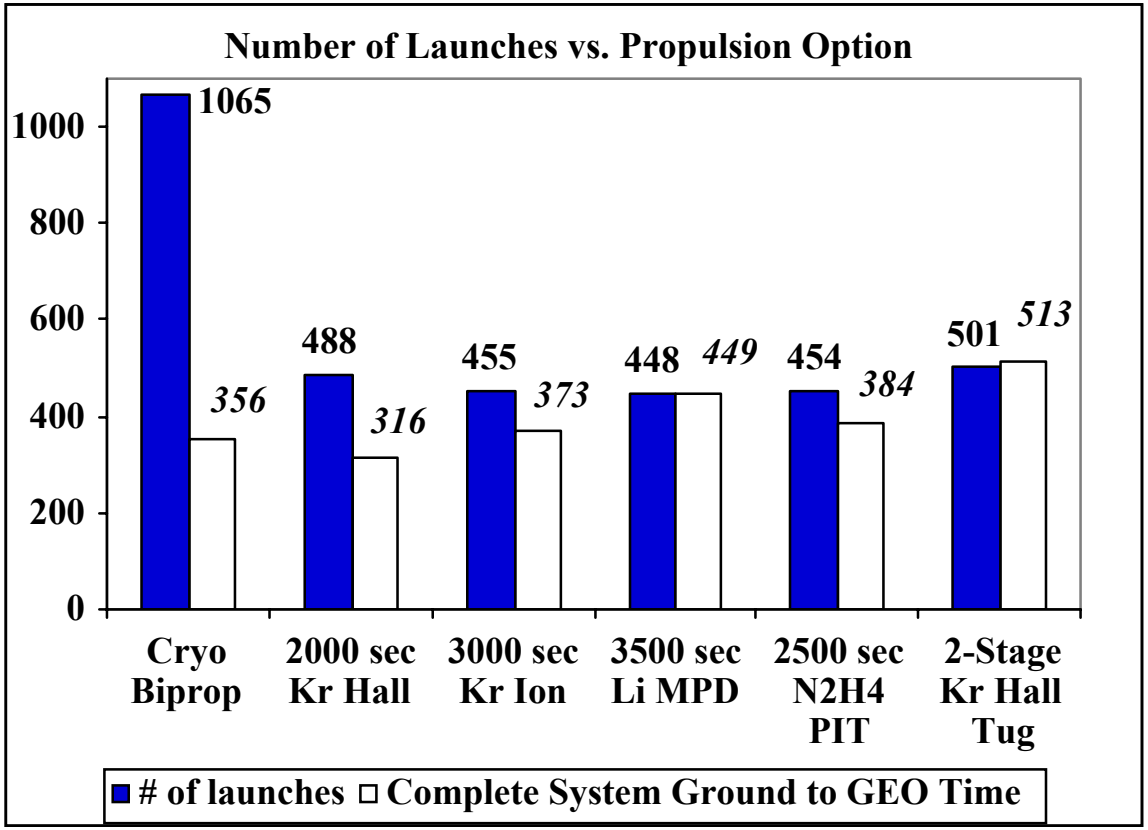
# Comparison of Launch Fleet and Complete Sun Tower Ground to GEO Time




- **All Electric Propulsion Concepts More than *Halve* the number of launches compared to chemical**
- **Hall system provides shortest Ground to GEO time of *all* system options**

Space Solar Power
-- Solar Electric Propulsion --

# MW Class MPD Thruster Development

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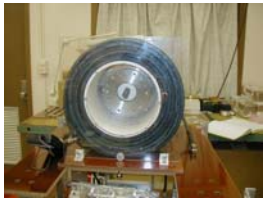
## FY 00

## FY 01

## FY 99

20 MW ***Pulsed*** Power Capacitor Bank



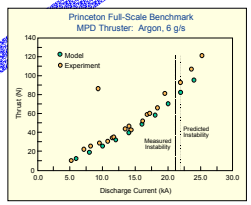
High Power ***Pulsed*** MPD Hardware Fabrication

Tank 1 Modifications for High Power ***Pulsed*** MPD Research

High Power ***Pulsed*** MPD Hardware Testing 1 to 20 MW

High Power ***Pulsed*** MPD Hardware Designed

Numerical Simulation of MPD Plasma Performance




High Power ***Pulsed*** MPD Hardware Testing 1 to 20 MW

Design, Build and Test Nozzle for proper expansion

Self Field Testing - Goal 50% efficiency

**<u>TASK OBJECTIVE</u>: DEVELOP MW-CLASS MPD THRUSTER FOR SPACE SOLAR POWER SATELLITE PROPULSION APPLICATIONS**

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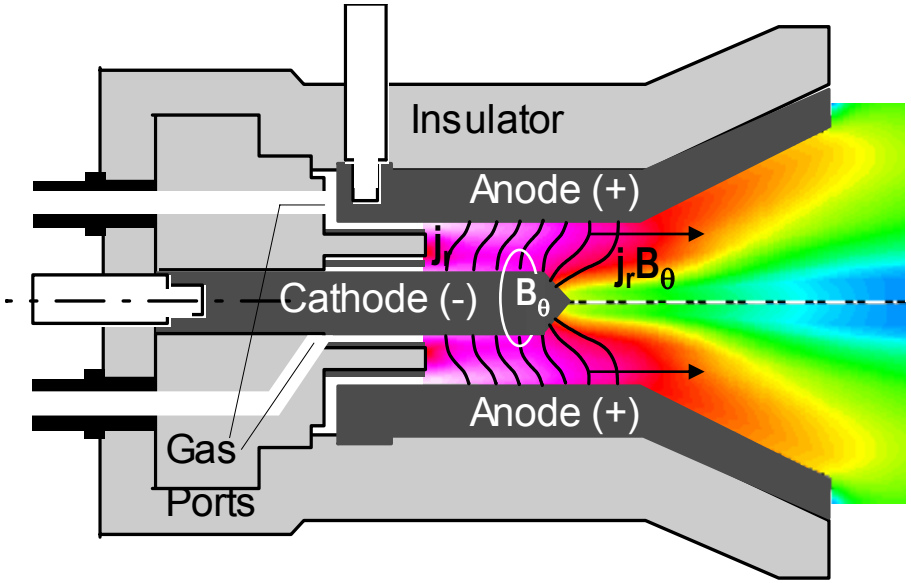
# HIGH POWER MPD THRUSTER

## MACH2 CODE SIMULATIONS




Predicted current density contours and mass density contours overlaid on MY-II MPD thruster geometry

**MACH2 used to simulate Japanese MY-II MW-class experimental thruster:**

- Self-field and applied-field MPD operation
- Power levels from 0.5-6 MW
- Hydrogen, 4 kA < J < 18 kA
- 10 N < Thrust < 80 N
- 8% < Efficiency < 36%

**Wide parameter range to validate MACH2 simulations**

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# HIGH POWER MPD THRUSTER

## PROGRAM STATUS AND PLANS

- **MPD Program Status:**
  - Pulsed test facility operational
  - Baseline thruster tested to 2-MW
  - Minor facility bugs corrected

- **FY02 Program Plans**
  - **2nd/3rd Quarter:**
    **Baseline self-field & applied-field thruster tests**
    *Goal: 40% self-field, >50% applied-field*
  - **3rd/4th Quarter:**
    **Nozzle-anode self-field thruster tests**
    *Goal: 50% self-field efficiency*

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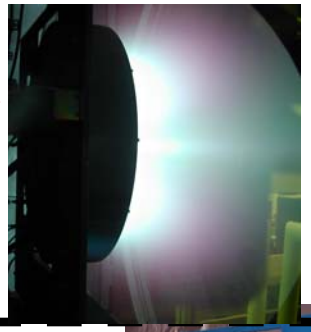
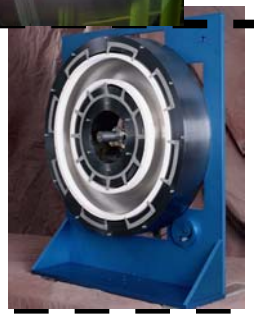
# Space Solar Power
# -- Solar Electric Propulsion --
# 50 kW Hall Thruster

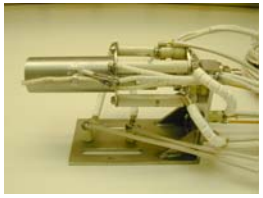
**FY 02**

Test 50 kW
Hall Thruster



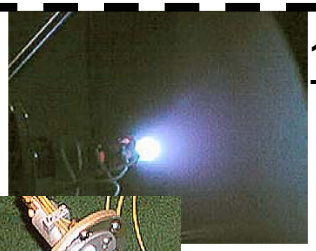


2nd Generation
GRC Design,
Build, and test
100 amp Cathode



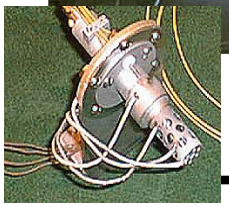
**FY 01**

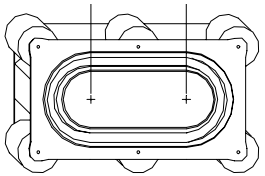
GRC In-House Design
and Build50 kW Hall
Thruster



100 amp Cathode
Testing

**FY 00**



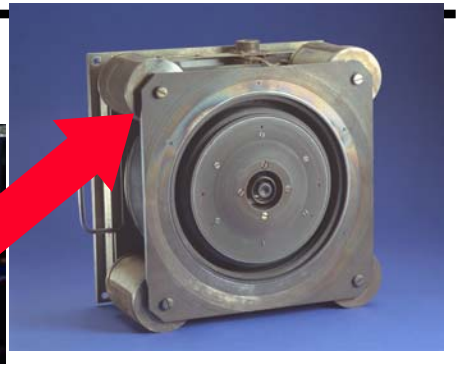


Domestic 50 kW Hall
Thruster Design

Low Voltage, High Thrust Hall
Thrusters Study

GRC Designed
and Built 100
amp Cathode

**FY 99**



Russian High Power Hall Tests

High Power Thruster
Feasibility Study

50 kW Hall Thruster
Development

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# High Power Electric Propulsion State-of-the Art: Hall

1.5 kW On-Orbit

50 kW NASA 457 M Demonstrated

5 kW Flight Qualified

10 kW 1000 hr test

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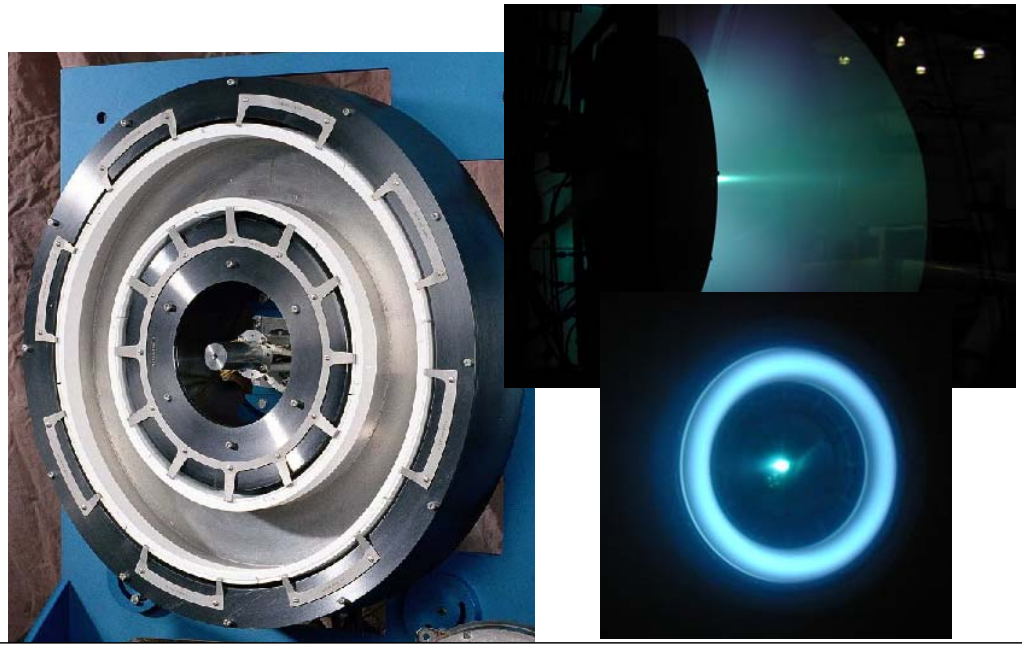
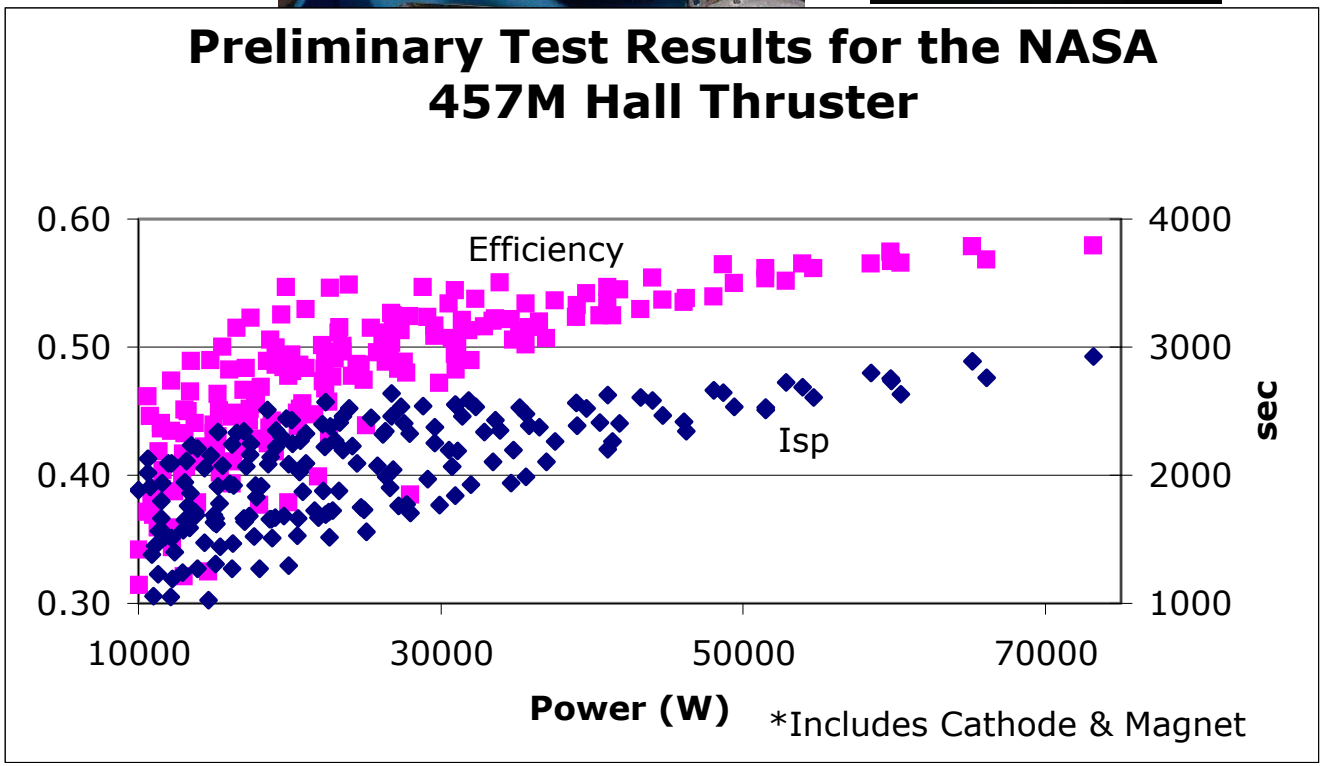
# NASA 50 kW Class Hall Development



**Demonstrated Performance (discharge)**
**Isp = 1500 to 3000 sec**
**Thrust = 0.4 to 3.0 N**
**Eff = 40 to 59%**
**Power: 10 to 72 kW**
**10x SOA**

**Designed, Fabricated, Tested In-House GRC**



# Conclusions

- Mission and System Analysis used to determine best technology options/paths
- High power Hall and low Isp MPD pursued
- High Power Hall Designed, Built, and Tested Successfully for
  - Space Solar Power
  - HEDS missions
  - Future Commercial Missions
- Future Work
  - Determine impact of using more power for transportation
  - Develop Krypton (or other propellants) for the Hall Thruster




# Backup Slides

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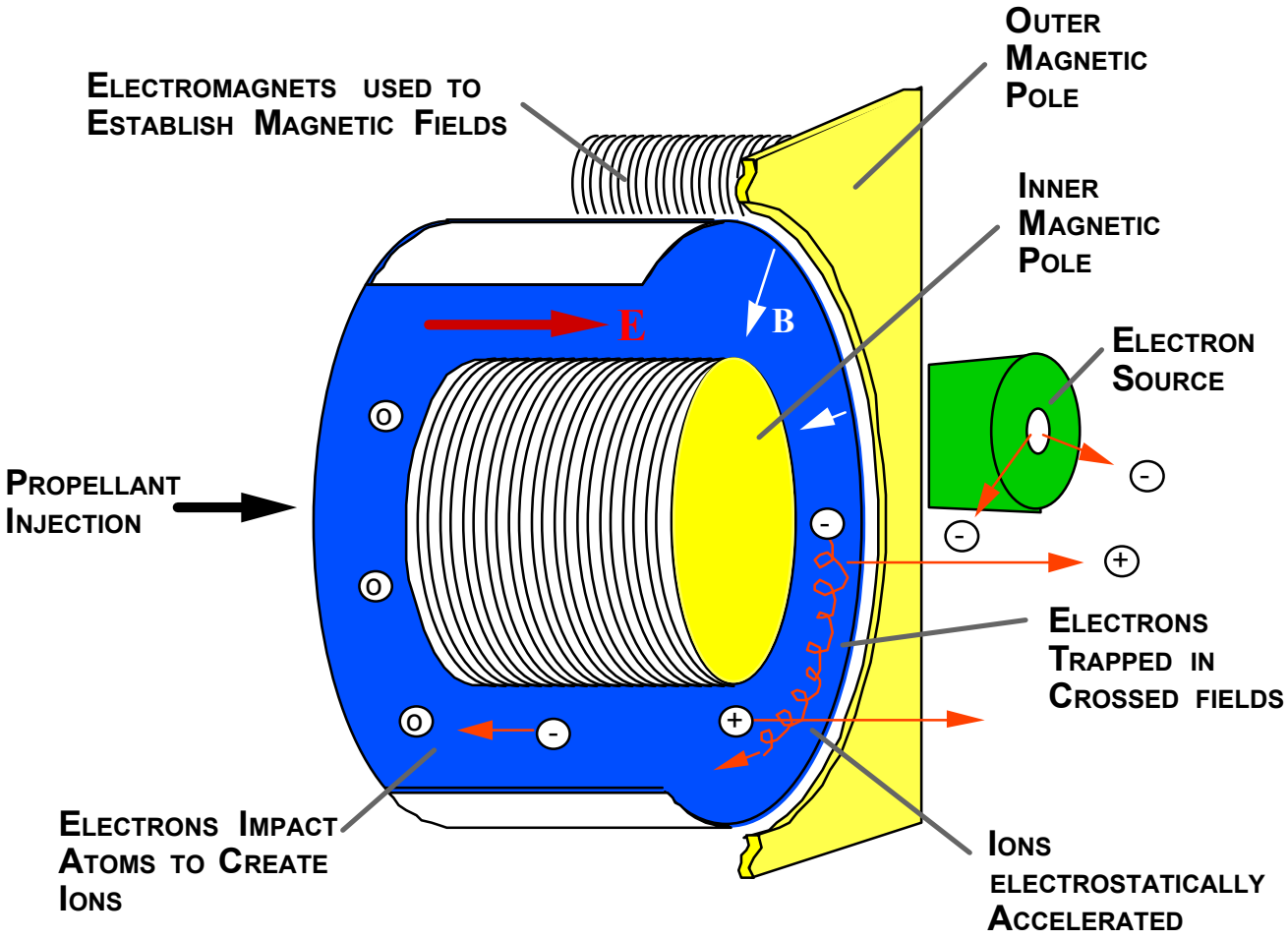
# Hall Basics

## HALL ACCELERATOR



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# Magnetoplasmadynamic (MPD) Basics